Announcements

- Homework for tomorrow…

  Ch. 29: CQ 10, Probs. 20, 22, & 54

  CQ4a) $E_1 = E_2 = -(10\ \mathrm{V/m})$ ihat b) $E_1 = -(5\ \mathrm{V/m})$ ihat, $E_2 = -(20\ \mathrm{V/m})$ ihat

  CQ5: accelerates right

  29.6: W = 1.6×10^{-13} J

  29.12: $E_x(0\mathrm{cm}<x<2\mathrm{cm}) = +2{,}500$ V/m $E_x(2\mathrm{cm}<x<3\mathrm{cm}) = -10{,}000$ V/m

  29.44: $E = 40$ V/m, $\theta = 27°$ ccw from $+x$-axis

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 29

Potential & Field

(*Combinations of Capacitors*)

Review…

- *Kirchoff's Loop Rule…*

$$\boxed{\Delta V_{loop} = \sum_i (\Delta V)_i = 0}$$

- *Conductors in Electrostatic Equilibrium…*

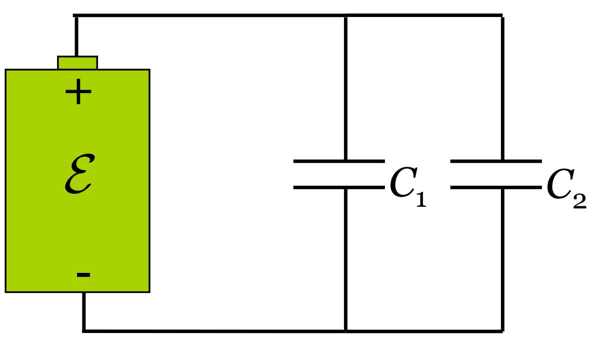
- *Capacitance…*

$$\boxed{C \equiv \frac{Q}{\Delta V_C}} \qquad C = \frac{\epsilon_0 A}{d} \quad \text{(parallel-plate capacitor)}$$

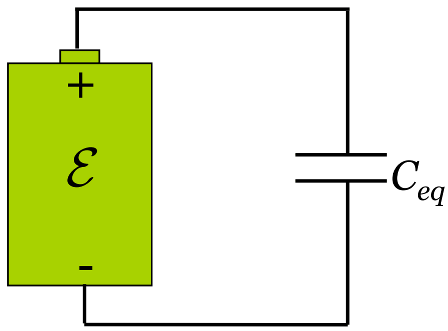
Combinations of Capacitors

Consider two capacitors in *parallel*…

- Can we find an *equivalent capacitor*, C_{eq}, to the two capacitors, C_1 & C_2?



$\stackrel{?}{=}$



$\Delta V_B = \Delta V_1 = \Delta V_2$

$Q = Q_1 + Q_2$

$C = \frac{Q}{\Delta V}$

$Q = C\Delta V$

$Q_1 = C_1\Delta V$

$Q_2 = C_2\Delta V$

$Q_{eq} = C_{eq}\Delta V_{eq}$

$C_{eq}\Delta V = C_1\Delta V + C_2\Delta V$

$C_{eq} = C_1 + C_2$

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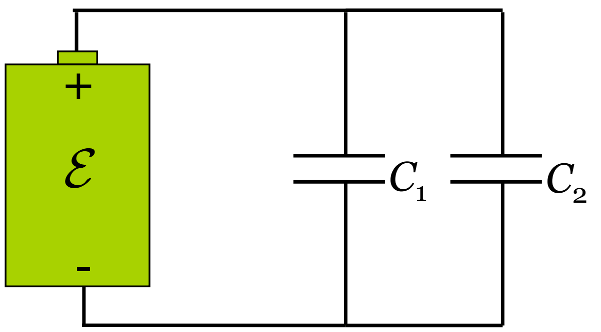

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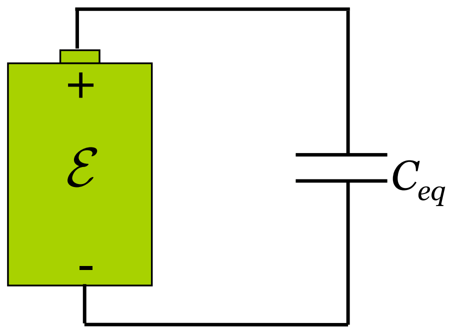


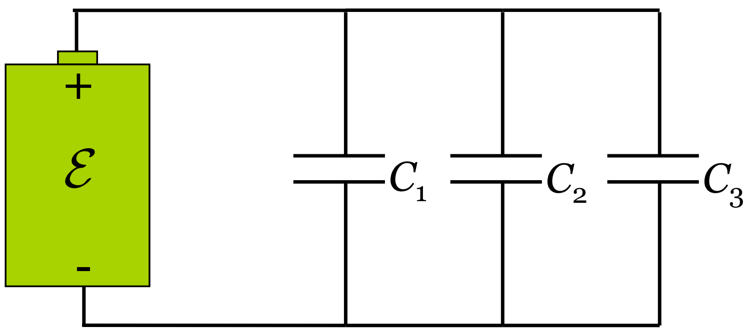
- YES!

$$C_{eq} = C_1 + C_2$$

Combinations of Capacitors

What about for *several* capacitors in *parallel*?

- Can we find an *equivalent capacitor*, $C_{eq,}$ to the capacitors, C_1 , C_2, … *(all in parallel)*?



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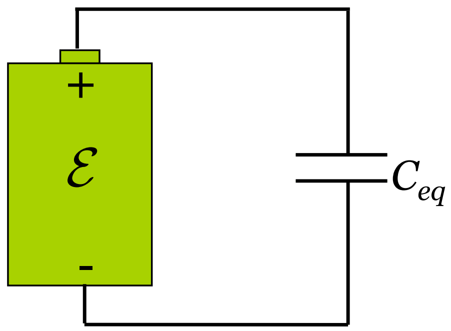

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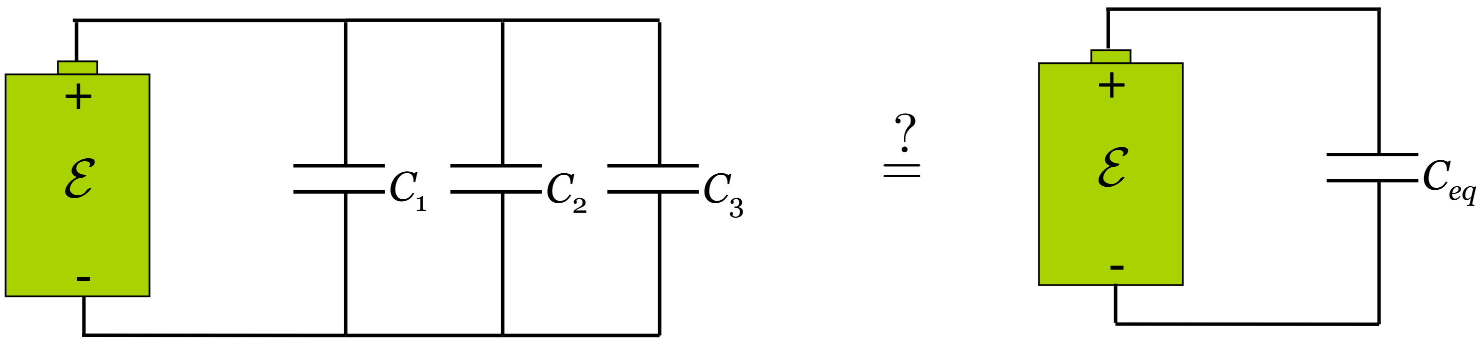
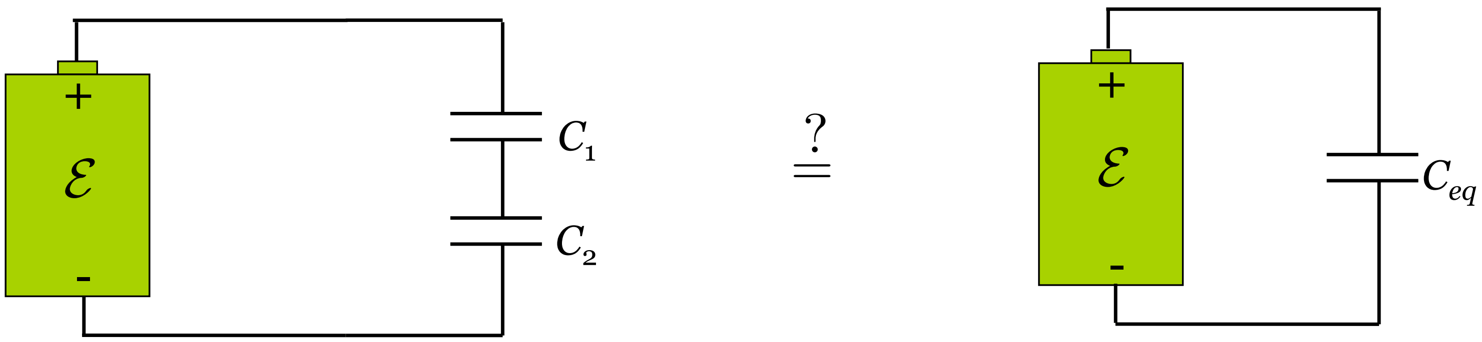


$$C_{eq} = C_1 + C_2 + \ldots$$

Combinations of Capacitors

Consider two capacitors in *series*…

- Can we find an *equivalent capacitor*, C_{eq}, to the two capacitors, C_1 & C_2?



1.) $\Delta V_{Bat} = \Delta V_1 + \Delta V_2$

2.) $Q = Q_1 = Q_2$

$C = \frac{Q}{\Delta V} \therefore \Delta V = \frac{Q}{C}$

$\Delta V_1 = \frac{Q_1}{C_1}$

$\Delta V_2 = \frac{Q_2}{C_2}$

$\Delta V_{eq} = \frac{Q}{C_{eq}}$

Plugging into 2)

$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2}$

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$

Combinations of Capacitors

Consider two capacitors in *series*…

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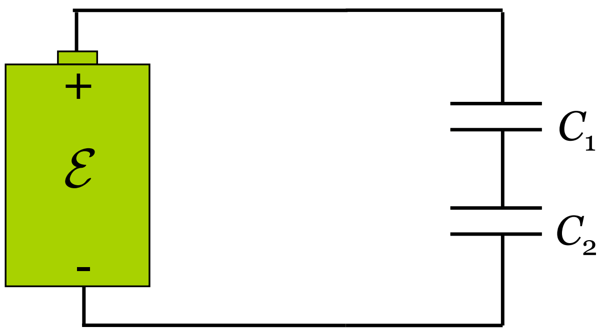

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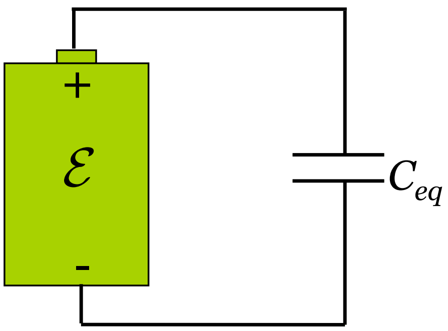


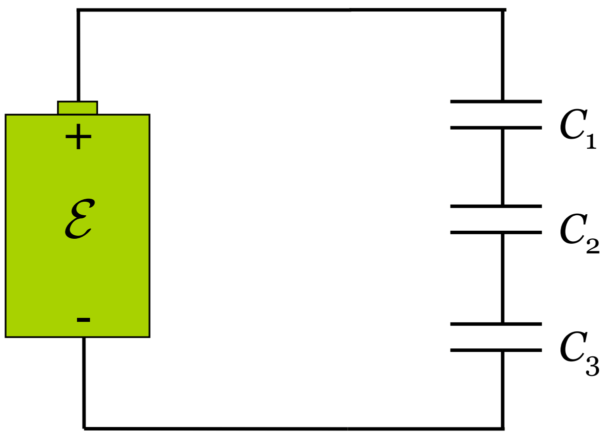
- YES!

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Combinations of Capacitors

What about several capacitors in *series*?

- Can we find an *equivalent capacitor*, $C_{eq,}$ to the capacitors, C_1 , C_2 ,... *(all in series)*?



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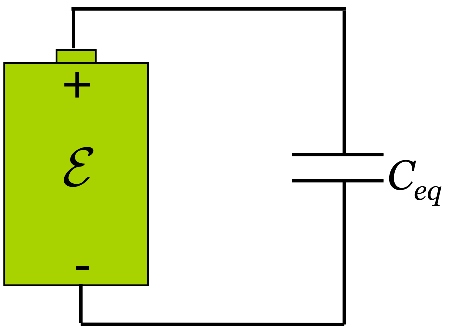

Combinations of Capacitors

What about several capacitors in *series*?

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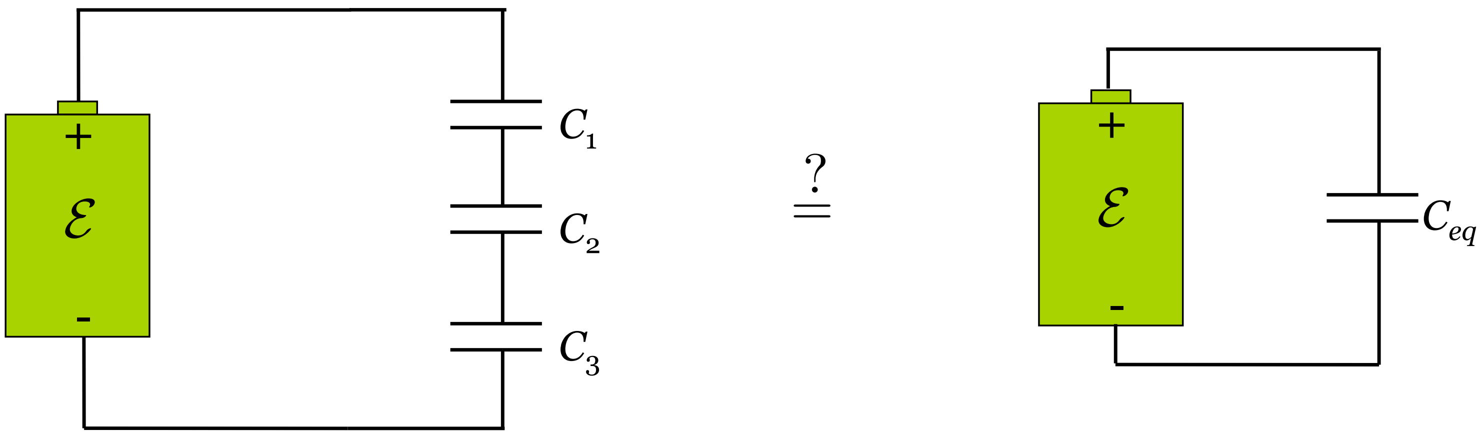
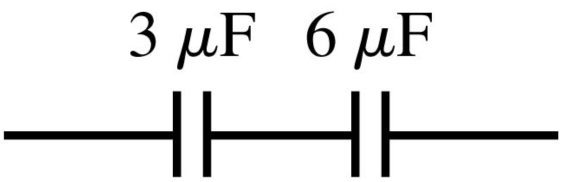


$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$$

Quiz Question 1

The equivalent capacitance is



1. 9 μF.
2. 6 μF.
3. 3 μF.
4. 2 μF.
5. 1/2 μF.

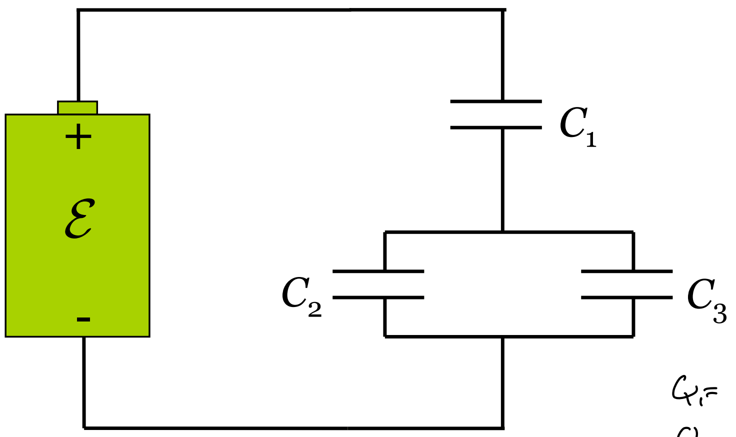
$$\frac{1}{3uf} + \frac{1}{6uf} = \frac{3}{6uf} = \left(\frac{1}{2uf}\right)^{-1} = C_{eq}$$

$$C_{eq} = 2uF$$

i.e. 29.7: A Capacitor Circuit

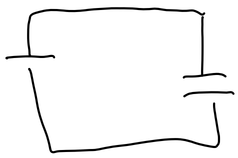
Find the charge on and the potential difference across each of the three capacitors in the figure below.

Given: $\mathcal{E}$ = 12 V, C_1 = 3 μF, C_2 = 5 μF , C_3 = 1 μF



$C_2 + C_3 = 6\,\mu F = C_4$

$\frac{1}{3uF} + \frac{1}{6uF} = \frac{1}{2uF} = 2uF$



$Q_1 = C_1 \Delta V_1$

$Q_2 = C_2 \Delta V_2$

$Q_3 = C_3 \Delta V_3$

$Q_{eq} = C_{eq} \Delta V_{eq}$

$= 2uF(12v)$

$Q = 2.4 \times 10^{-5} C$

$\Delta V_1 = \frac{Q_1}{C_1} = \frac{24uF}{3uF} = 8V$

$Q_1 = Q_4 = 24\,\mu C$

$\Delta V_4 = \frac{Q_4}{C_4} = \frac{24\mu F}{6\mu F} = 4V$

$\Delta V_2 = \Delta V_3 = \Delta V_4 = 4V$

$Q_2 = C_2 \Delta V_2$

$= 5\mu F(4v)$

$Q_2 = 20\,\mu C$

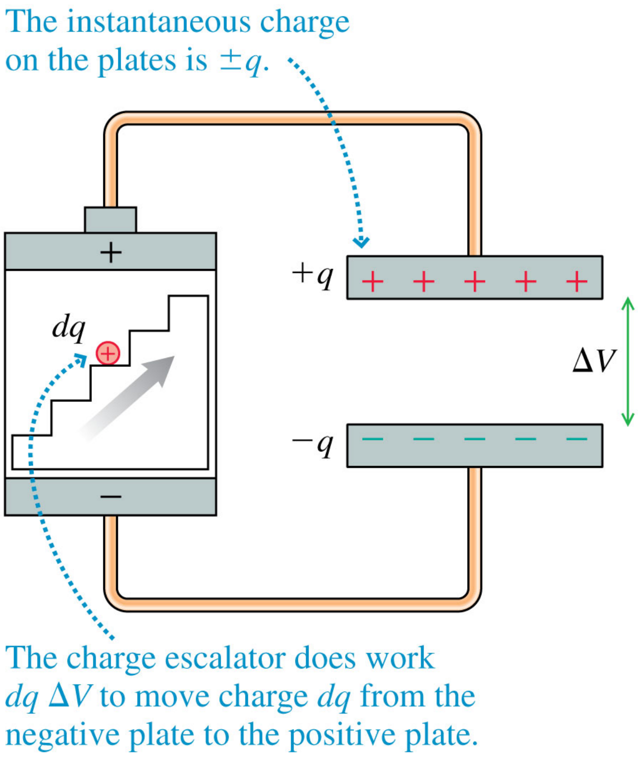
$Q_3 = C_3 \Delta V_3$

$= (1uF)(4V)$

$Q_3 = 4\,\mu C$

29.6: The Energy Stored in a Capacitor

How much *energy* is transferred from the battery to the capacitor?



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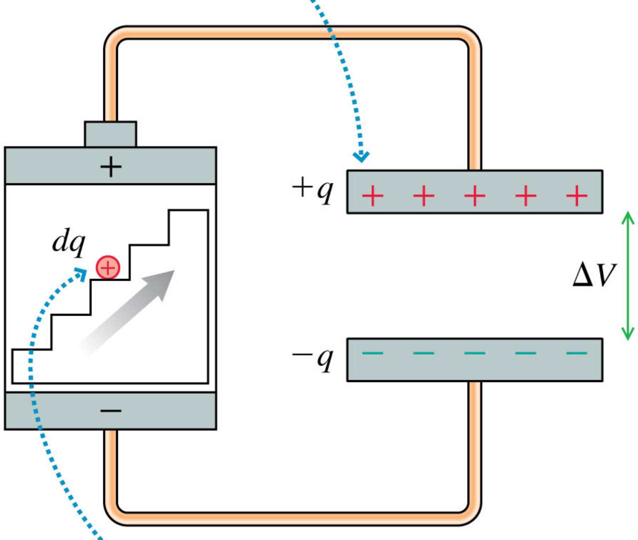
$$\text{Initially}: \; q = 0, \; U = 0$$

$$\text{Finally}: \; q = Q, \; U = U_C$$

29.6:
The Energy Stored in a Capacitor

How much *energy* is transferred from the battery to the capacitor?

The instantaneous charge on the plates is $\pm q$.



The charge escalator does work $dq\,\Delta V$ to move charge dq from the negative plate to the positive plate.

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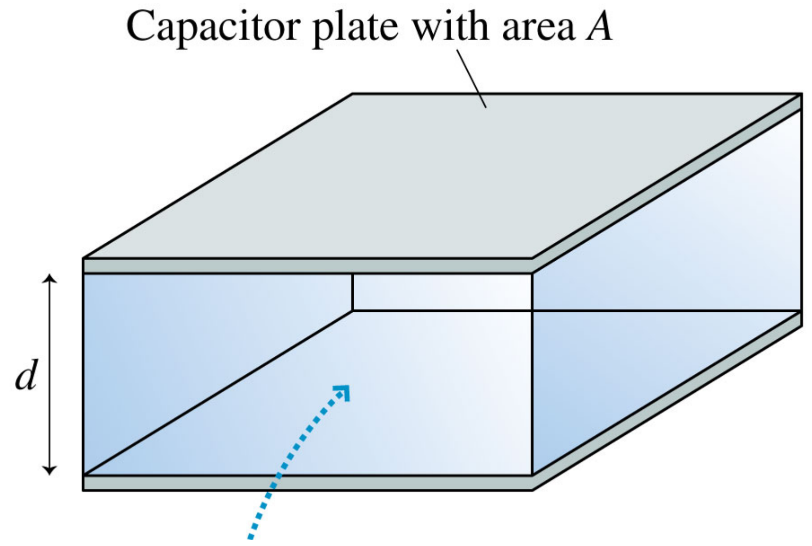
$$\boxed{U_C = \frac{Q^2}{2C}}$$

or

$$\boxed{U_C = \frac{1}{2}C(\Delta V_C)^2}$$

The Energy in the Electric Field

Q: If a capacitor is analogous to a stretched spring, *where* is the stored energy?



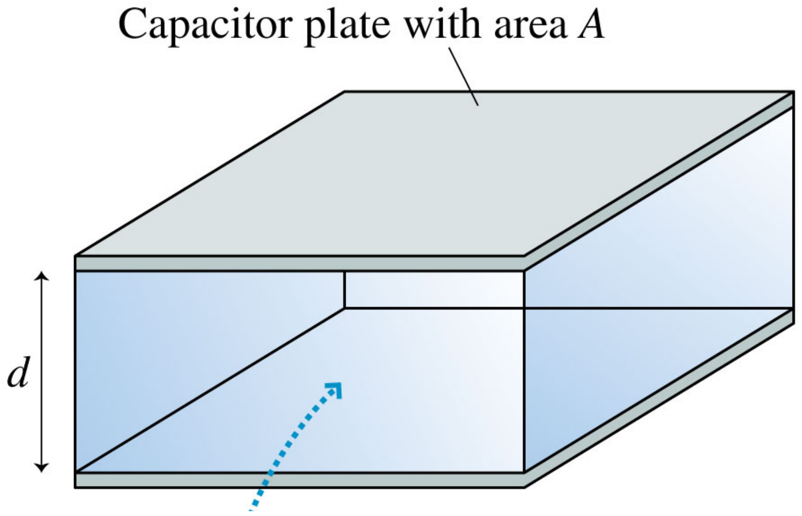
The Energy in the Electric Field

Q: If a capacitor is analogous to a stretched spring, *where* is the stored energy?

- A: In the E-field!

$$\boxed{u_E = \frac{1}{2}\epsilon_0 E^2}$$

$$\frac{\text{energy stored}}{\text{volume in which it is stored}}$$



When the capacitor is discharged, the energy is released as the E-field *collapses*.